DESIGN METHOD
OF A HELICOPTER COCKPIT

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Abstract

The paper describes the problems of developing a helicopter crew cabin layout which are solved within the scope of the task of making compatible two essentially different components: technical details of a cabin and human performance.

Heterogeneity and multicriteria aspects relevant to the cockpit layout are investigated with priority given to behavioral engineering in search of technical solutions.

From the functional standpoint the crew cabin is the focus of the main relationships of the helicopter systems. Therefore, a variety and multipurpose nature of the relationships which are to be accounted for in designing a cockpit layout give rise to a variety of its structure at different design phases.

The paper addresses the task of designing a crew cabin layout and its parameters selection at the early stages of helicopter development which hold a peculiar place in the design process and represent the conceptual decision making phases. In this connection the cabin structure is based on the fundamental interfunctional relationships being a starting point in designing a crew cabin layout as a complete helicopter component which reflects its application roles and operational features. It allows to restructure it, to form the lists of necessary reference data and to select the engineering solutions.

Based on the generalized experience of Kamov Design Bureau the design solution procedure of a helicopter cockpit and its structure are examined within the twin-level design task (Fig.1).

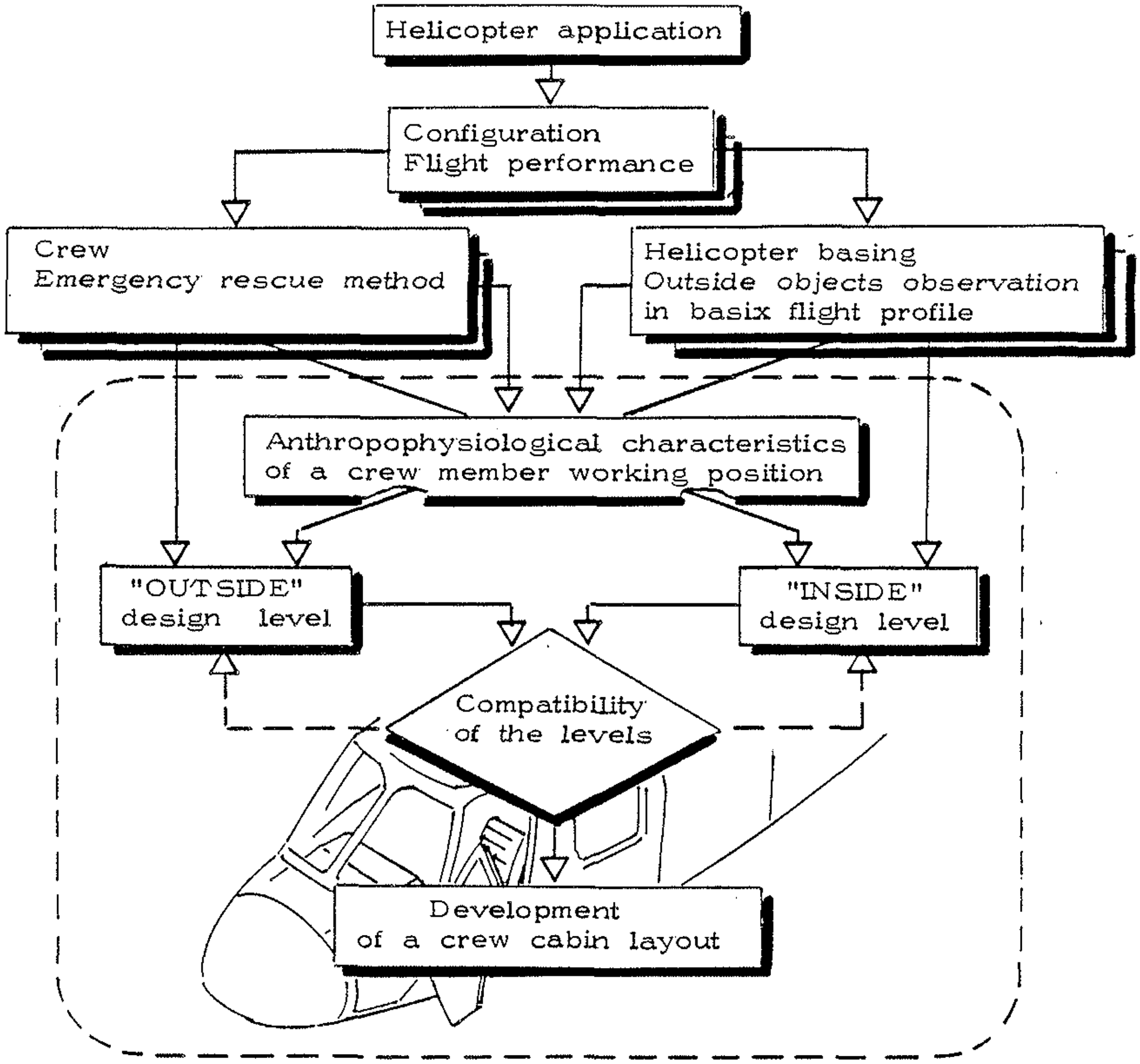


Fig.1 Generalized scheme of a helicopter crew cabin design procedure.

- At the "OUTSIDE" design level the questions of inter-connection between cabin parameters and crew stations within "crew-helicopter" system are addressed and the task of cabin compatibility in the general helicopter configuration is solved.

- At the "INSIDE" design level crew station layout of the "crew-cabin" system is arranged and the main parameters of cockpit systems and accessories are determined in accordance with its design concept.

Analysis of the cockpit structural interfaces and the trend of their influence shows that cockpit layout is based on the arrangement of its information - control field which is topologically integrated and functionally subordinate to an operator position (his motor and information fields). It predetermines the priority of a working position arrangement in designing cockpit layout since being an integral reflection of human activity potential it defines the quality of his functional activity.

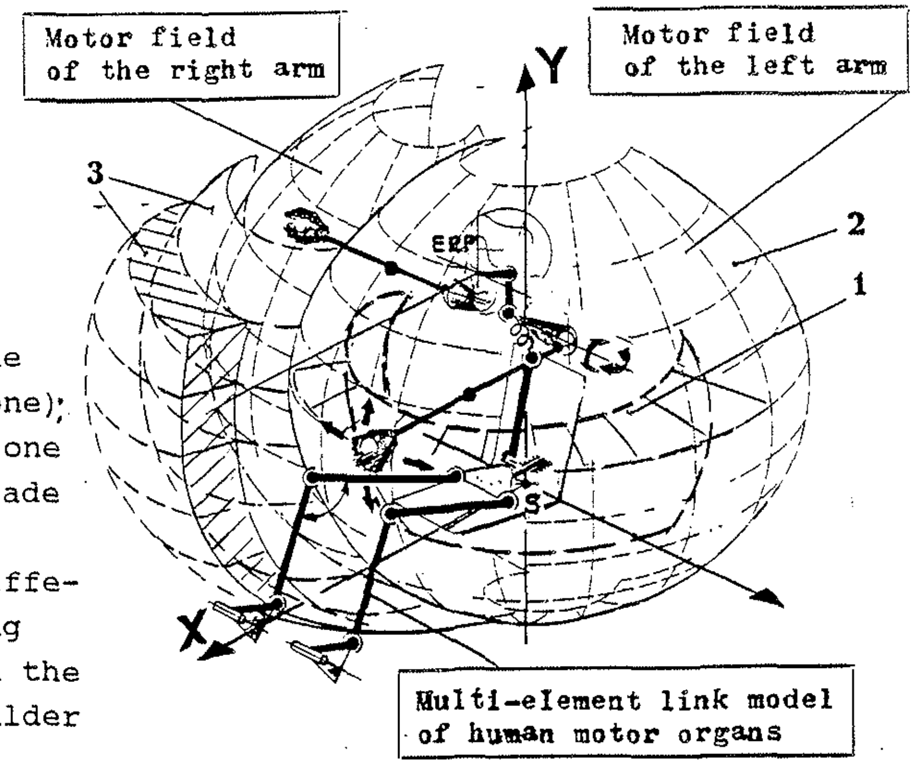
This is a key statement, because it allows to define the hierarchical structure of a crew cabin, to formulate the design algorythm and to determine the parameters of its components.

The design level decomposition is realized such that the search fields of cockpit design solutions are homogeneous.

The design procedure of a cockpit layout is based on imitational models using a method of mathematical correlation of crew station parameters in terms of anthropometric data of corresponding working positions.

A multi-element link model of human motor system similar to a well - known model [1],[2] was used as a basic one to define the working positions and was subdivided into functional submodels to select parameters of separate crew station elements (Fig.2). Analytical functions have been revealed for each submodel which establish the relationship between the main anthropometric data when a working position changes dynamically.

The submodels took into account anthropometric data variations of the pilot population in the range of 5th to 95th percentiles.



1- easily reach zone (active motor zone);
2- limiting reach zone with shoulder-blade immobile;
3- reach zone in different body bending positions within the confines of shoulder harness.

Fig.2 A portion of the arms motor field submodel in operator seating position with different reach envelopes when his position changes.

Fig.3 graphically shows the essence of the "OUTSIDE" design level by the areas of cockpit functional influence on the helicopter layout.

- "a" area has the required zones $\alpha = f(\Psi)$ of outside forward vision and, hence, constraints for the cabin nose part design appear.
- "b" area influences landing-gear scheme selection and the bottom part of the cabin structure when energy-absorbing survival means are used. Their structural characteristics and arrangement should be compatible with vertical speed, Vy, in emergency landing and acceptable energy-absorbing stroke, H, of an operator seat.
- In the "c" area the locations of the landing gear legs and protruding elements on the fuselage sides are tailored to the crew cabin doorway, its dimensions are determined to ensure a parachute drop safety in a specified range of helicopter flight speed, V .

- If an active pilot escape system is used in a helicopter [3], the initial portion of ejection trajectory is defined in "d" area. By changing the initial parameter, Θ, of ejection trajectory and residual rotor element parameter, l_i , after the blades are fired the trade-off ejection seat position, L , (as to point S) relative to the rotor shaft is determined.

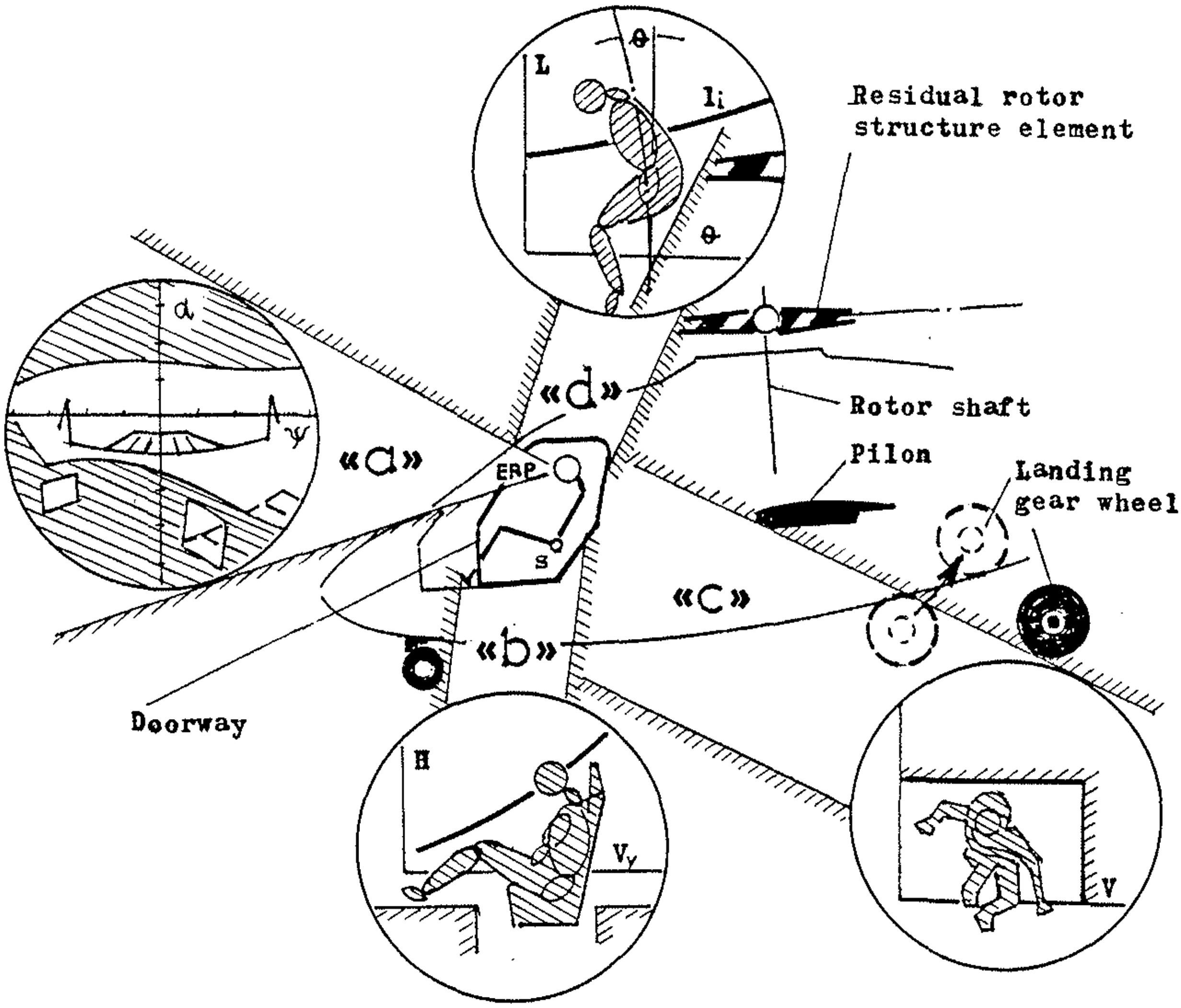


Fig.3 Areas of crew cabin functional influence on the helicopter configuration

The "INSIDE" design level is aimed at making up various cabin configurations, crew station layouts in accordance with the crew working positions, justified functionally. The volume and the content of this level are shown in Fig. 4.

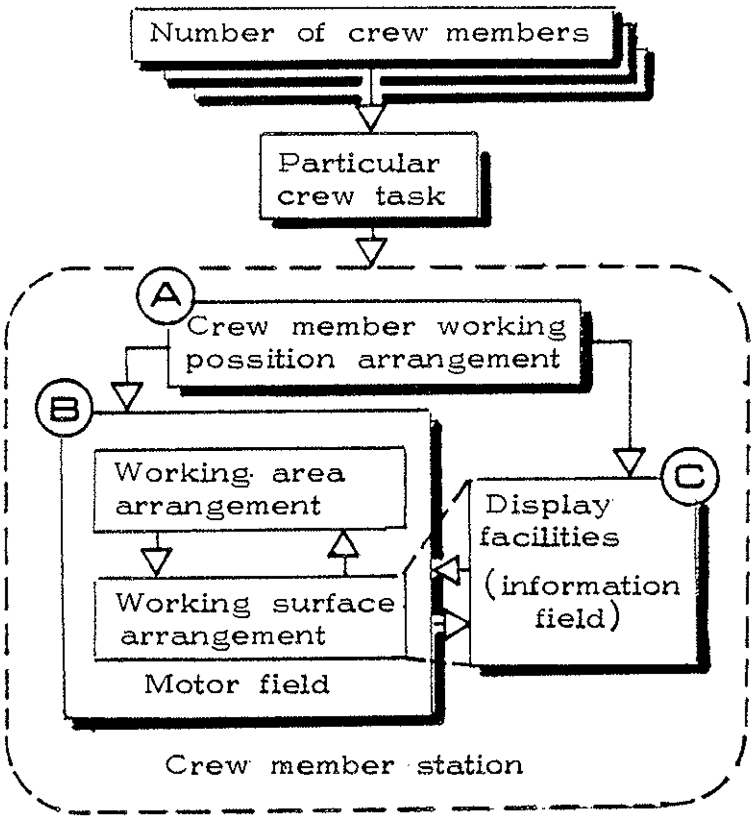


Fig.4 Development structure of a crew member station.

Blocks "A" and "B" are responsible for spatial arrangement of a crew cabin volume, its working zones, working surfaces and vision ranges which form a certain crew station layout functionally connected with an operator senso-motor activity; block "C" is formed on the elements of blocks "A" and "B". It allows to shape block "C" at the early stage of crew cabin development and to relate the solutions of its elements within the scope of designing blocks "A" and "B".

Mutual correspondence of the organizational and functional cockpit design principles between blocks "A" and "B" predetermines strict order in designing their components. Fig.5 illustrates such an order showing a layout version of a pilot station where pilot seat and main helicopter controls occupy higher levels in the subordination hierarchy since they function as support surfaces which make up a pilot working position.

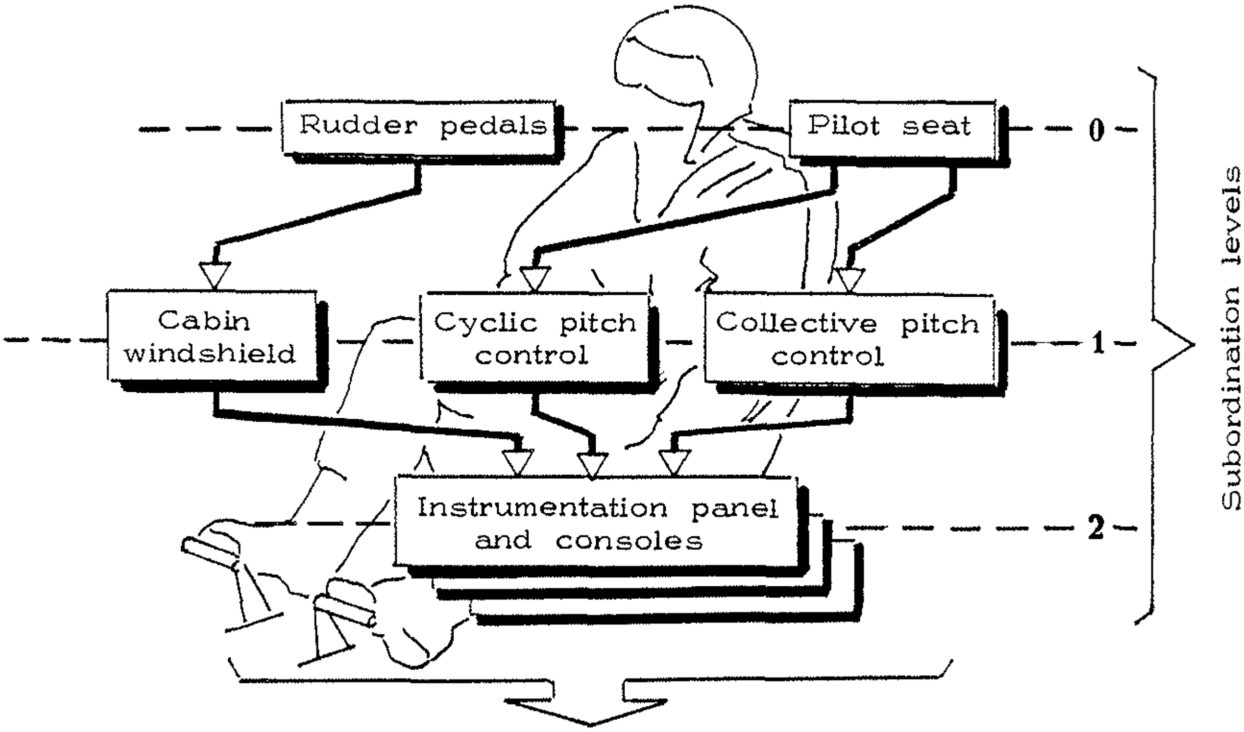
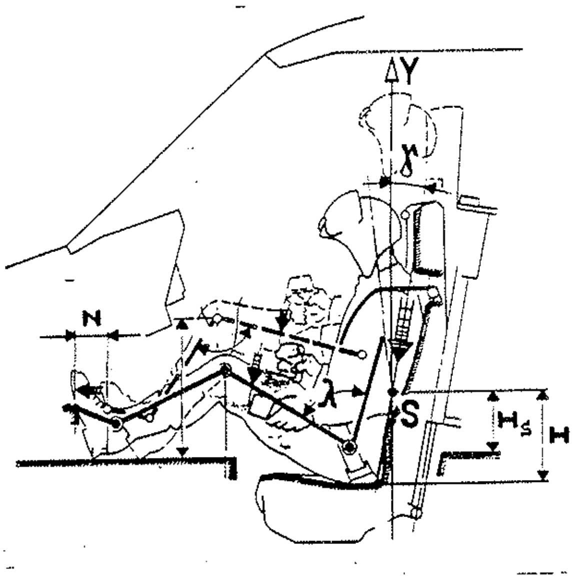


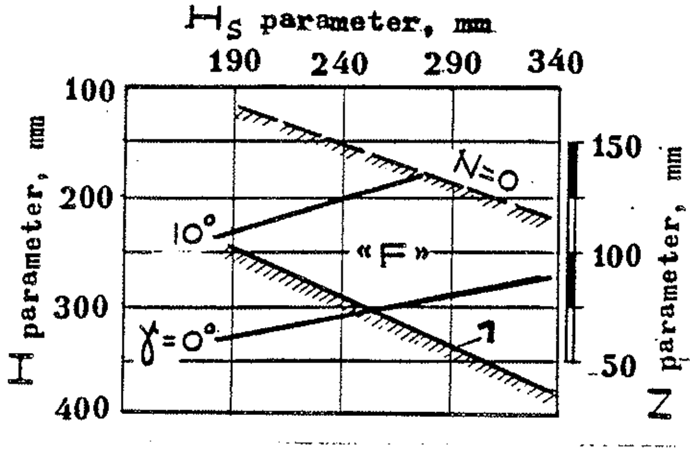
Fig.5 Subordination structure in designing the main pilot station elements.

This subordination particularly manifests itself when energy-absorbing devices are used to ensure crew survival in case of emergency landings. The task of layout compatibility of energy-absorbing seat and helicopter control and that of correlation between their functional and controllable travels is solved with strict interface to a required rearrangement of a pilot working position to provide his safety. The layout of the instrumentation panels and on-board equipment consoles is designed with due account of providing unobstructed space for such rearrangement.

Fig.6 shows a segment of correlation between kinematic parameters of energy-absorbing seat and rudder pedals. In this illustration a correlation criterion is the bending angle limit, λ , of the hip joint providing for pilot legs safety during dynamic rearrangement of his working position in the process of energy-absorbing seat stroke. Test results revealed that angle limitation is $\lambda \geq 75°$.

γ - trajectory slope of the seat energy-absorbing stroke.





I - allowable range "F" of the seat energy-absorbing strokes such that to provide pilot arms safety.

Fig.6 A segment of a pilot position submodel to correlate seat energy absorbing stroke, H, and additional travel of rudder pedals, N.

The results of correlation shown in diagram of Fig.6 testify to the necessity of introducing a special device into pedals to ensure their additional travel forward of the pilot during energy-absorbing stroke.

The crew station design solutions for each element of blocks "A", "B" and "C" of the "INSIDE" level and "a" area, "c" area (doorway dimensions) and if energy-absorbing seat is used - "b" area (seat stroke parameters) of the "OUTSIDE" level are coordinated within a single software of the design process and are formalized in a layout using computer graphics (Fig.7).

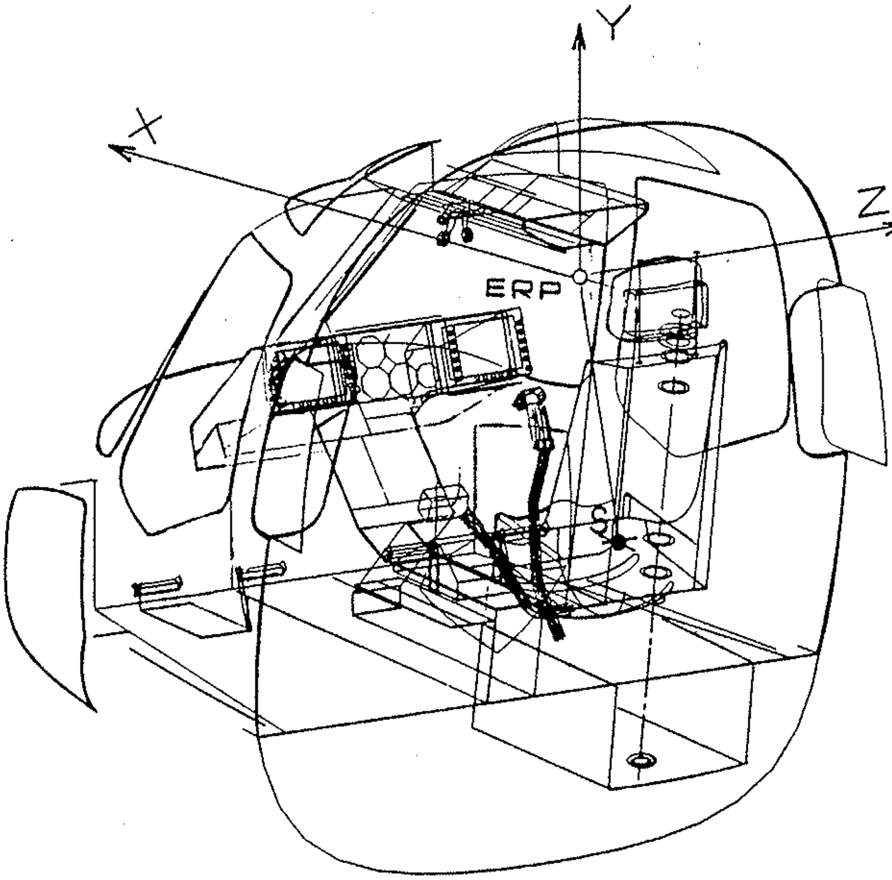


Fig.7 Three-dimensional model of a helicopter cockpit layout.

The results of the study of "pilot-aircraft-environment" system functioning show that visual perception of the environment (both outside and in-cabin) dominates all the pilot activity components necessary to build-up adequate flight contents and due to this all other modalities of the perception process are subordinate to it [4].

This fact is reflected in the methodology of design solutions correlation to the information-control field of the crew cabin by simulating the perception of these solutions in motor and information fields of a pilot station.

"A principle of realism" is the basis of simulation which means that a model generates the effect of a "designer presence" in a vehicle without its material realization.

The diagrams of flat representation of object space in bi-central cylindrical projection are used for simulation. A high level of correspondence between the displayed picture of object space on a diagram and a real one is seen in Fig.8 comparing the two pictures in reference to the KA-126 helicopter cockpit.

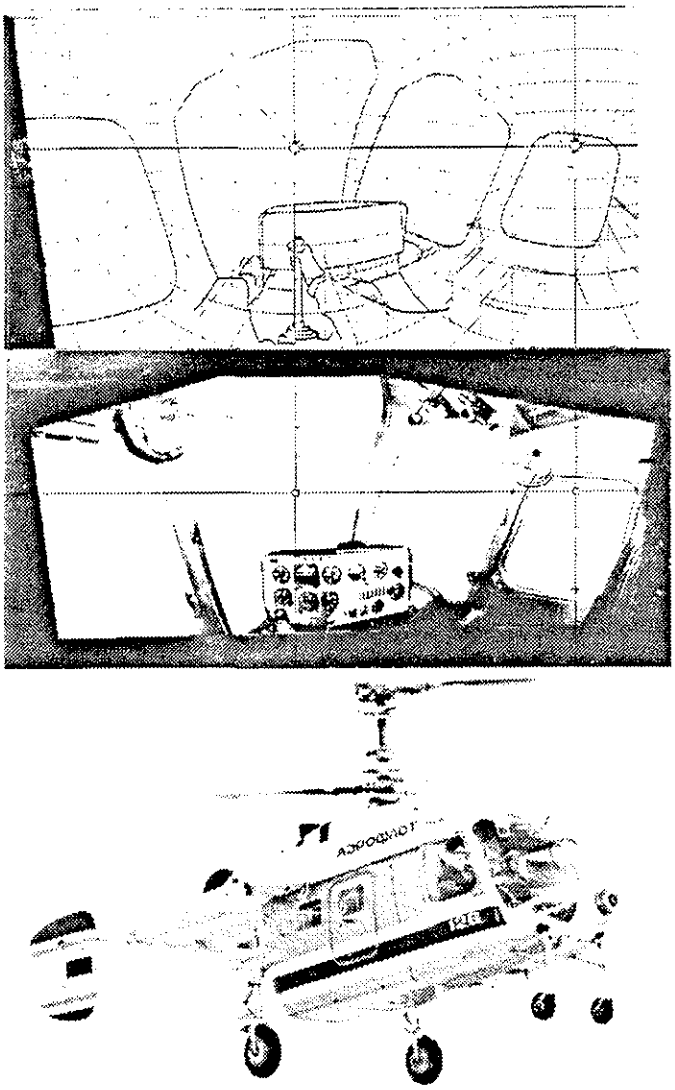
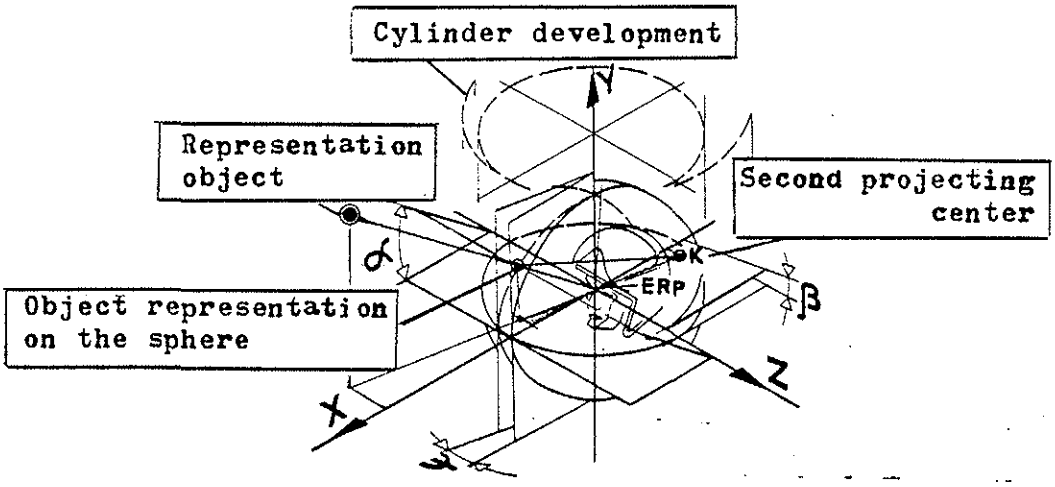


Fig.8

The diagram has a three-dimensional metric structure (Fig.8 shows the diagram structure in the form of a three-coordinate grid with angular parameters) and allows to carry out a dialogue with the cabin object space simulated on it, followed by a reconstruction of the solutions resulted from the dialogue in orthographic projection and vice versa.

Three-dimensional object representation on the diagram is shown in Fig.9.



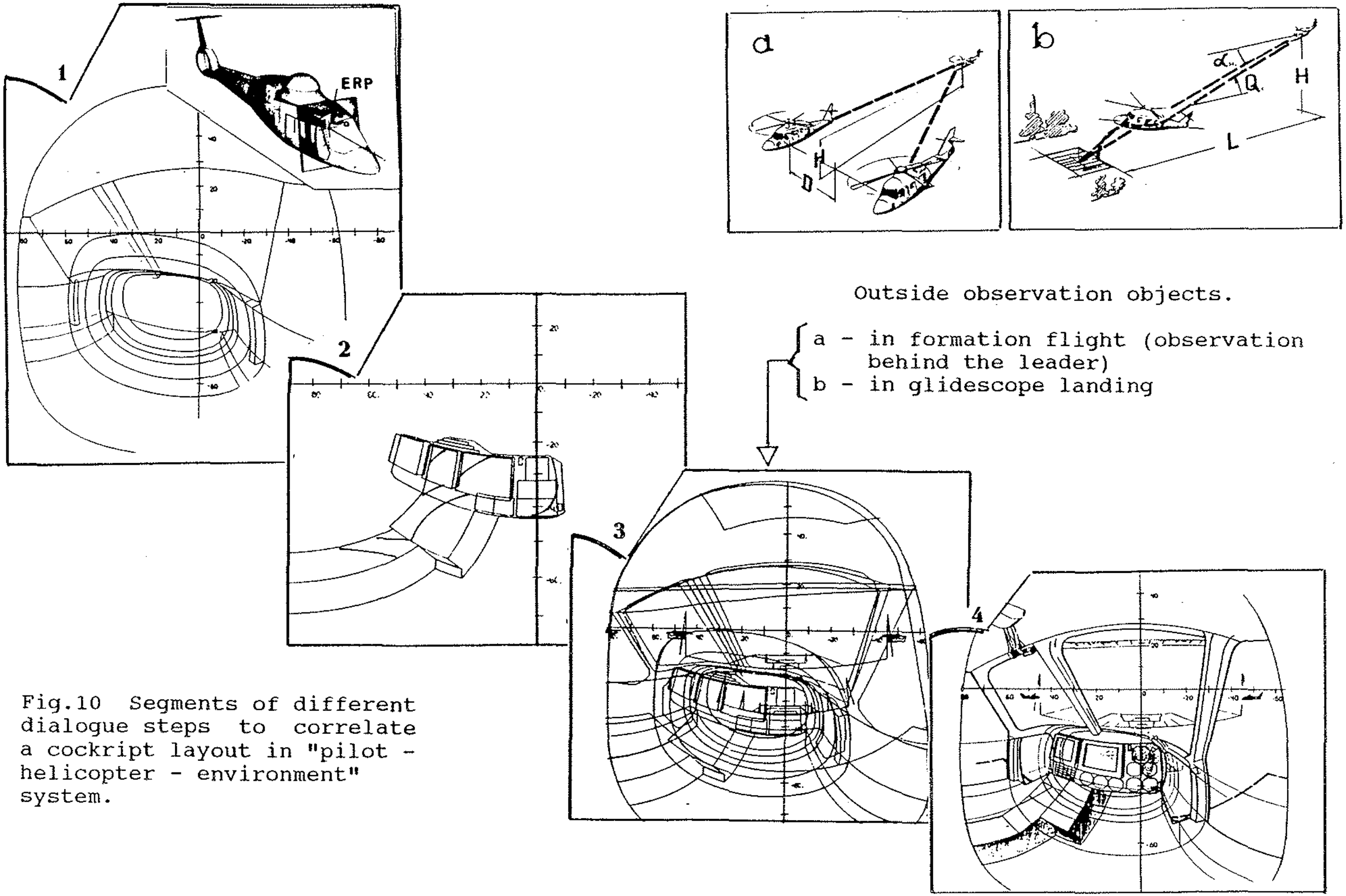
α , β, $\hat{\psi}$ - object angular parameters on the diagram show the projected values of similar angular parameters in the orthographic projections.

Fig.9 Simulation of spatial subject representation in bi-central cylindrical projection.

The object is imaged from the eye reference point (ERP) onto the mathematical sphere surface which center coincides with ERP. Afterwards the spherical picture is topologically mapped from the second projection centre, "K", in the aft portion of the equatorial sphere plane onto the circular cylinder surface, tangent to the sphere, which development results in an object representation model in bi-central cylindrical projection.

The design dialogue consists of:

- correction of instrument panel surface orientation such that their positions correspond to various zones of an operator sensor-motor field;
- changes of the instrumentation panel geometries;
- correction and shaping of the outside vision local zones for a set of typical flight profiles;
- correction of theoretical outlines of the fuselage nose part.



Outside observation objects.

a - in formation flight (observation behind the leader)
b - in glidescope landing

Fig.10 Segments of different dialogue steps to correlate a cockript layout in "pilot - helicopter - environment" system.

The dialogue structure is based on logically related simulation procedures of the cabin object space to ensure compatibility of design solution at the "OUTSIDE" and "INSIDE" levels in "crew-helicopter-environment" system.

Fig. 10 illustrates the contents of separate dialogue procedures, where:

1 - representation of theoretical outlines and different airframe elements typical for cabin layout;

2 - representation of instrument panel and equipment consoles; their correlation with motor and information fields of a pilot;

3 - diagram of overlaid representation according to steps 1 and 2 in the pilot information field where windshield corrections are introduced to provide for reference outside object observation in typical flight profiles;

4 - results of the solution corrections according to step 3.

The results of correlation in the course of a dialogue are formalized into integral diagrams of the cabin three-dimensional space representation of various contents which allow:

- to make a proximate evaluation of a layout solution of the crew cabin information-control field;
- to evaluate the quality of cockpit visibility performance as function of the change of the outside objects observation angles along the flight trajectory.

Fig.12 gives an example of an integral diagram of the object-information space of one of the KA-32 helicopter versions (Fig.11).

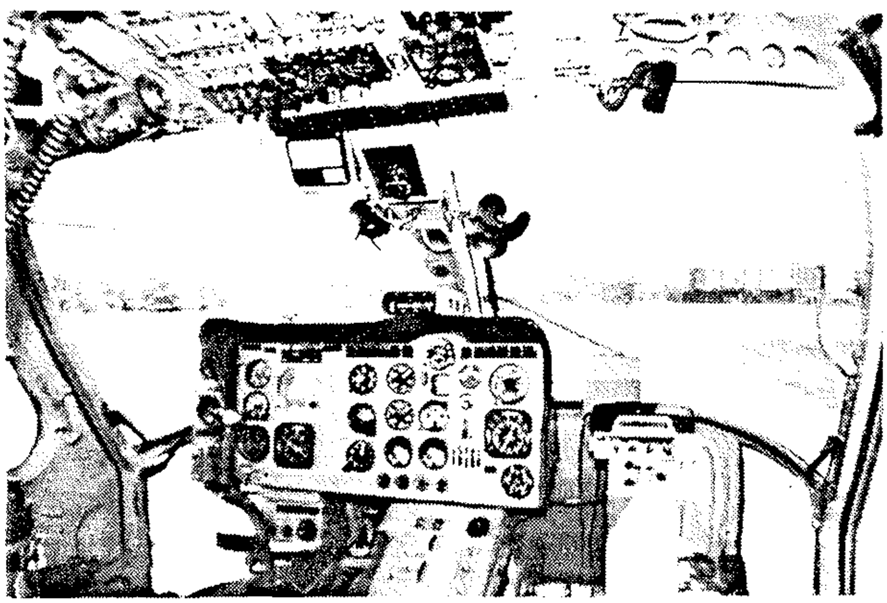


Fig.11

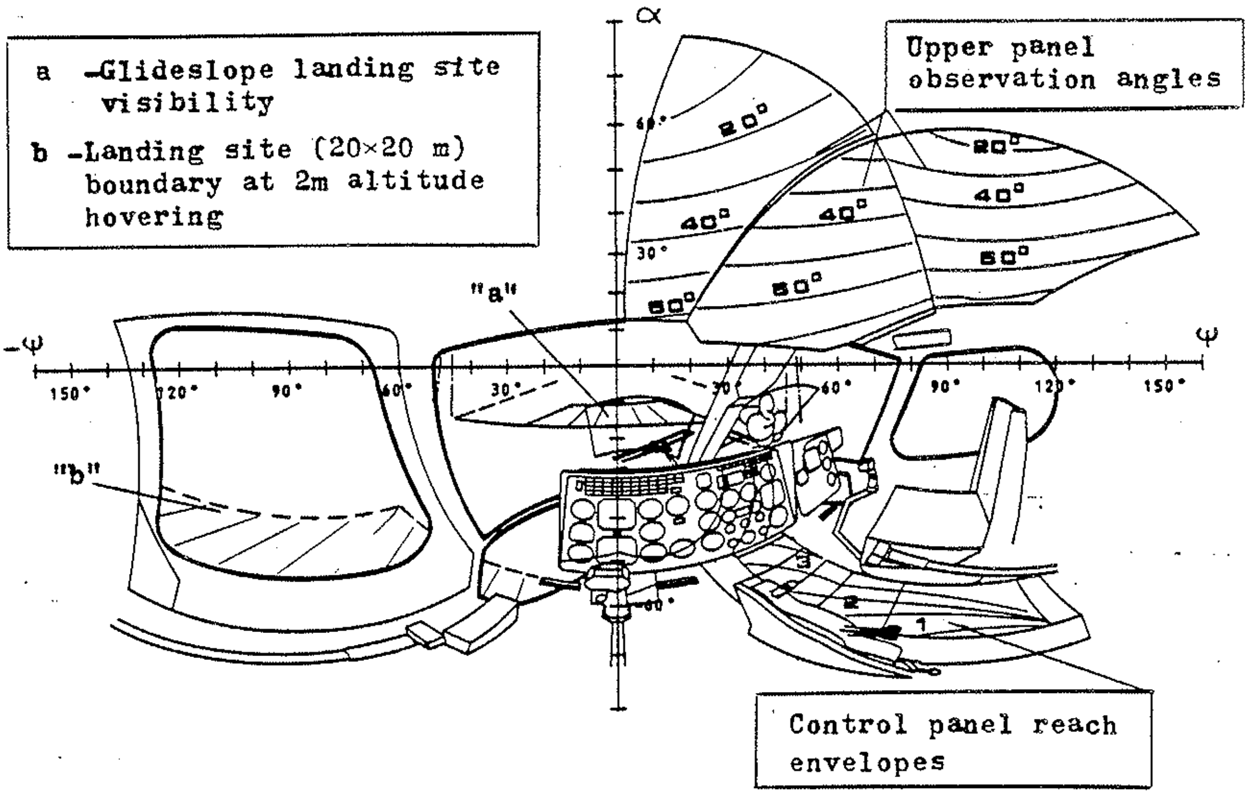


Fig.12 Integral diagram of object-informational representation of the KA-32 crew cabin space as seen from the left pilot seat.

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